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50. Internationales Wissenschaftliches Kolloquium
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Kuang-Chyi Lee / Po-Ting Tsai

The Setup of a Vision-Based Robot Soccer

ABSTRACT

In this paper, we implement SOC soccer robot with a RF CCD. We integrate the PWM drive velocity control system, the communication system, the encryption/decryption circuit, the position encoder/decoder circuit and software differential into an FPGA chip by VHDL hardware language. The tracking control of soccer robot is based on image feedback from the RF CCD. The experimental results show that soccer robot can communicate with the host via RF module within a range of 30 meters, the speed of communication can reach 6 kbps and the velocity of soccer robot can reach 10 km/hr. The vision-based soccer robot can be extended to the other mobile robot's application with minor modification.

INTRODUCTION

The game of robot soccer is developed to prove the effectiveness of the algorithm of robotics and artificial intelligence. The researchers compete with each other through a standard task in this experimental platform to compare whose strategy and hardware are better. They usually use a single chip processor like 8051 or DSP with a complex drive and communication circuit to develop the control system of soccer robot. Besides, there is not vision system on the soccer robot. Dadios and Maravillas [1] adopted a fuzzy algorithm to control the two wheels of the soccer from the input data of distance and angle. Huang et al. [2] adopted the single chip AT90S4434 to implement robot soccer and to do position control by the phase locked loop (PLL). Hou [3] had implemented robot soccer by an FPGA chip. The angle velocity was calculated to drive the soccer by a fuzzy algorithm. Lee and Bien [4] put forward the method to recognize things with fuzzy theory. Search for the accurate corner by utilizing relation of intensity of edge and gradient. Although the traditional vision system of robot soccer, which is hanged overhead on the playground, can acquire the overall image of full playground. The CCD on robot soccer can get the detail environmental data.

This paper will use an SOC structure to integrate the RF communication system, motor control module, image feedback system and the software differential into a single FPGA chip through VHDL hardware language. The robot soccer communicates with host computer through the RF module. The software differential transfers straight-and-angular velocity command of the host to be the rotational speeds of the left and right wheels. The rotational speeds of wheels are control by the PWM drive signal. The result of this SOC robot soccer can compact the size of soccer's hardware, make the soccer to be more controlled, and reduce the developed time of the strategy.

FPGA SYSTEM OF SOCCER ROBOT WITH VHDL

The systematic structure of soccer robot is show in Figure 1, the signal from host PC is received by 433MHz RF module. Through the decryption circuit, the drive command will be deciphered. The drive command will be translated to the rotational speed of wheels by the software differential. Then the motor of wheels will be controlled by PID and PWM controller. All the harware programs will be integrated into one single FPGA of Altera 1K100QC208. And the physical soccer robot is shown in Figure 2. The robot communicates with host computer through the RF module. The software differential transfers straight-and-angular velocity command of the host to be the rotational speeds of the left and right wheels. The rotational speeds of wheels are control by the PWM drive signal. The result of this SOC soccer robot can compact the size of robot's hardware, make the robot to be more controlled, and reduce the developed time of the strategy. Although the traditional vision system of soccer robot, which is hanged overhead on the playground, can acquire the overall image of full playground. The CCD on robot can get the detail environmental data, so the robot can be guided by this vision system.

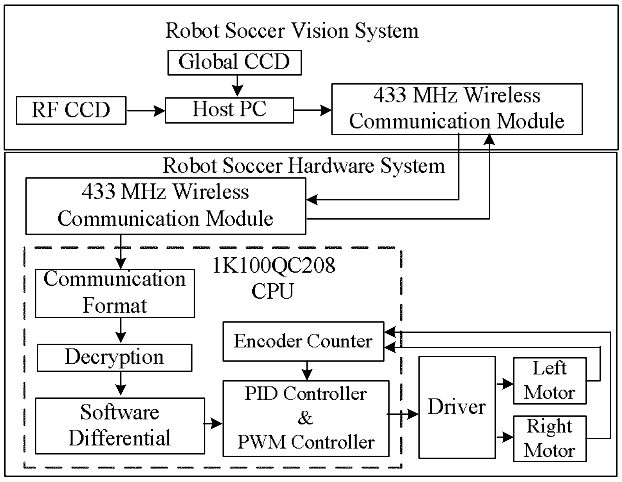

Figure 1. The systematic structure

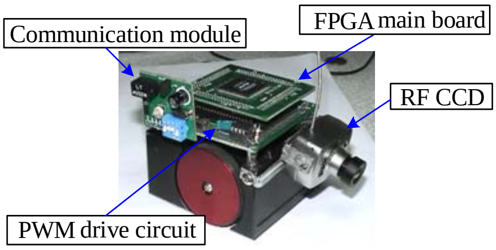

Figure 2. The picture of soccer robot

VHDL COMMUNICATION SUBPROGRAM

The traditional serial transmission through RF wireless module is easily erroneous with high transmit rate. The VHDL subprogram of RF module is shown in Table 1. In this subprogram, we used the SAE J1850 standard[5] to transmit the RF data. When the data are transmitting, the signal adopts the method of VPM (variable pulse width). The signal continues going high and going low. When the signal is at high level, the long-high signal indicates data bit ' 0 ' and the short-high signal indicates data bit ' 1 '. When the signal is at low level, the long-low signal indicates data bit '1 ' and the short-low signal indicates data bit ' 0 '. It starts to receive the data from the long-high signal (SOF) and it ends at an extremely long low signal (EOF). The encrypting/decrypting process and CRC process will be used during the data transmission.

```
if n'event and n ='1' then
if RX ='1' then en< ='1';  else en< ='0'; bt< ='1'; end if;
if en ='1' then count< =count+1; count2< ="00000000";
else count2< =count2+1; count< ="00000000"; end if;
if count ="00010100" and bt ='1' and rev / ='1' then
rev< ='1'; count< ="00000000"; bt< ='0'; end if;
if rev ='1' then
if count2> ="00001011" then buff (9) < ='1'; end if;
if count2 ="00000100" then buff< ='0'&buff (9 downto 1); count3< =count3+1; end if;
if count ="00000100" then buff< ='1'&buff (9 downto 1); count3< =count3+1; end if;
if count> ="00001110" then  buff (9) < ='0'; end if;
if count ="00010100" and count3> ="1001" then ev< ='0'; count3< ="0000"; end if;
end if; end if;
```

Table 1. VHDL Subprogram of Receiving Signal from the RF Module

HARDWARE CIRUIT OF DECIPHERS

Figure 3 shows the design encryption and deciphers the hardware circuit in the communication system. It is conveyed 0110 0011 while anticipating the data, suppose, 0110 0011 make with 11111111 XOR become 1001 1100 rotate it 3 position become 00100111 and then data in addition, wanton to count such as 4 right and then, 00100111 + 00000100 last results are 00101011, must tell this decoding method group's number of the hardware when being initial too while decoding some, it is that 00101011 - 0000 0100 is 00100111 to decipher the order, it is 1001 1100 to rotate 3 position doses left, make XOR and become 01100011 with 11111111 afterwards, it is the last data 99, such simple combined method can reduce the risk let out outside the data . The structure of conveying the data is divided into for mobile robot serial number (ID), speed value and angular speed are worth three parts. Mobile robot serial number can control the mobile robot anticipating controlling, enter the speed and angular speed number value before sending and wanting to control from the top management end, after calculating the speed of rotation which learns about mobile robot's wheel via the software differential mechanism, utilize PWM and divide into 127 levels to control.

```
if n'event and n ='1' then
if RX ='1' then en< ='1'; else en< ='0'; bt< ='1'; end if;
if en ='1' then count< =count+1; count2< ="00000000";
else count2< =count2+1; count< ="00000000"; end if;
if count ="00010100" and bt ='1' and rev / ='1' then
rev< ='1'; count< ="00000000"; bt< ='0'; end if;
if rev ='1' then
if count2> ="00001011" then buff (9) < ='1'; end if;
if count2 ="00000100" then
buff< ='0'&buff (9 downto 1); count3< =count3+1; end if;
if count ="00000100" then
buff< ='1'&buff (9 downto 1); count3< =count3+1; end if;
if count> ="00001110" then  buff (9) < ='0'; end if;
if count ="00010100" and count3> ="1001" then
rev< ='0'; count3< ="0000"; end if;
end if; end if;
```

Table 2 VHDL Subprogram of Receiving Signal from the RF Module

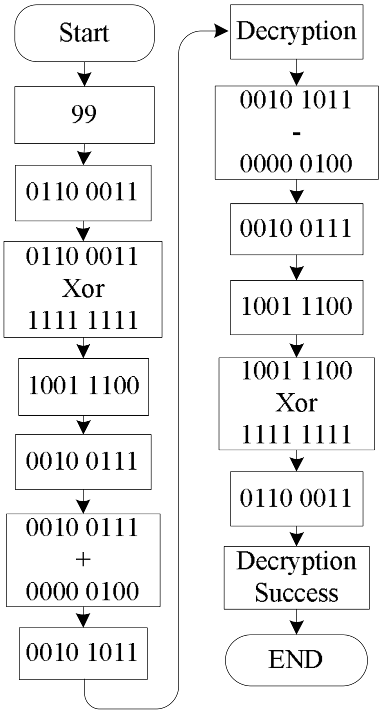

Figure 3. Procedure of encryption and deciphers

VHDL PROGRAM OF PWM DRIVER AND DECODING CIRCUIT

The software differential can obtain the rotational speeds of left and right wheels from the linear and angular velocities transmitted from the host computer. Then the controller will adjust the width of PWM pulse to control the rotational speeds of the motors. The VHDL subprogram to setup the PWM pulse is shown in Table 3. Where clk is an oscillator clock of 3MHz; cnt is a decreasing counter of D-type register; op is the output to drive the motor; and db is the input to adjust PWM pulse.

```
architecture pwm_ arch of pwm is
signal cnt : std _ logic _ vector (6 downto 0): ="1111111";
begin
process(clk)
begin
if clk'event and clk ='1' then
cnt< =cnt-1; end if;
end process;
op< ='1' when db> =cnt else '0';
end pwm _ arch;
```

Table 3. VHDL Subprogram of PWM Pulse

The VHDL subprogram of decoding circuit for the position encoder of motor is shown in Table 4. Where PA and PB are signals of phase A and B of encoder respectively; DA and DB are delay signals of PA and PB respectively; and cnt is the output counter of the position encoder of motor. The resolution of the encoder of motor adopted is 512 ppr. The decoding circuit will improve the resolution to 2048 ppr. The gear ratio between motor and wheel is 1:8. Thus, the resolution of wheel will be 360 / (512× 4× 8) =0.022° per pulse.

```
Signal DA, DB: std _ logic;
Begin
Process(clk)
If (rising-edge (clk)) then DA< =PA; DB< =PB; End if; End process;
if (not PA and DA) or (PA and not DA)or (not PB and DB) or (PB and not
DB) then
cnt< =cnt-1; else cnt< =cnt+1;
end if; end if;
```

Table 4. VHDL Subprogram of the Decoding Circuit

CORNER SEARCHING FROM IMAGE PROCESSING

The image system of soccer robot is used to recognize other robots (obstacles) and the football (target). Form the edge and corner data we can recognize the soccer robot from its pattern built in advance. After image preprocessing of edge detection, we propose an algorithm of gradient-comparison for the secant line which is shown in Figure 4. First, we set two secant lines in the contour f . Point P is start point and point Q must lead point S . We can set $x_3 = x_2 + 2$, $x_4 = x_2 + 3$, $m_1 = (y(x_2 + 3) - y(x_1))/(x_2 + 3 - x_1))$ is the slope of $\overline{PQ}$,and $m_2 = (y(x_2 + 2) - y(x_2))/2$ is the slope of $\overline{RS}$. x_2 can start form x_1 with an increment of one for every step to check whether $|m_1 - m_2|$ is larger than a threshold value T. The values of T are different for different objects, T of the soccer robot is 0.6 from experiments. If $|m_1 - m_2| \geq$ T then x_2 is a corner, and we can let $x_1 = x_2$ to find the next corner. The algorithm of gradient-comparison for the secant line is as the following:

(1) $m_1 = (y(x_2 + 3) - y(x_1))/(x_2 + 3 - x_1))$; $m_2 = (y(x_2 + 2) - y(x_2))/2$.
(2)If $|m_1 - m_2| \geq$ T then record x_2 to be a corner; let $x_1 = x_2$; goto (1).
(3) $x_2 = x_2 + 1$; goto (1).

The result of this algorithm for the soccer robot is shown in Figure 5. Three corners of the base of soccer robot can be used to find the distance, direction and orientation of soccer robot.

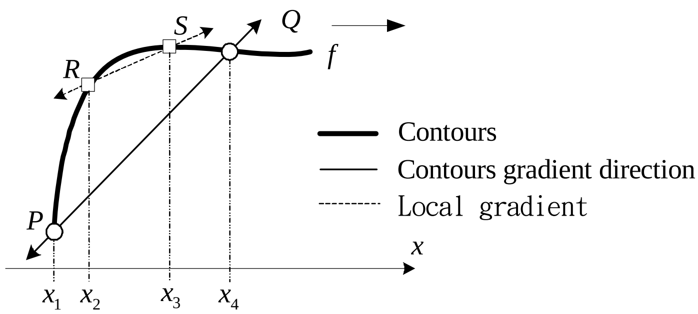

Figure 4. Gradient-comparison for the secant line

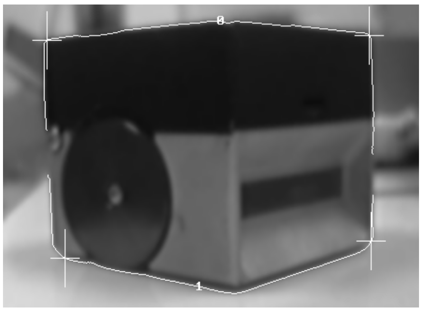

Figure 5. The corners of soccer robot

CONCLUSIONS

We have sucessfully implemented an integrated vision-based soccer robot with an FPGA chip by VHDL hardware language. The experimental results show that soccer robot can communicate with the host via RF module within a range of 30 meters, the speed of communication can reach 6 kbps and the velocity of soccer robot can reach 10 km/hr, and the image system can sucessfully find out the corners and edges of other robots.

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[4] Lee, K. and Bien, Z., "A Model-Based Machine Vision System Using Fuzzy Logic", International Journal of Approximate Reasoning, Vol. 16, No. 1, pp. 119-135, 1997.

[5] http://www.intel.com/design/intarch/papers/j1850_ wp.pdf.

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